Corrosion of Unexploded Ordnance in Soil Environments

December 18, 2001

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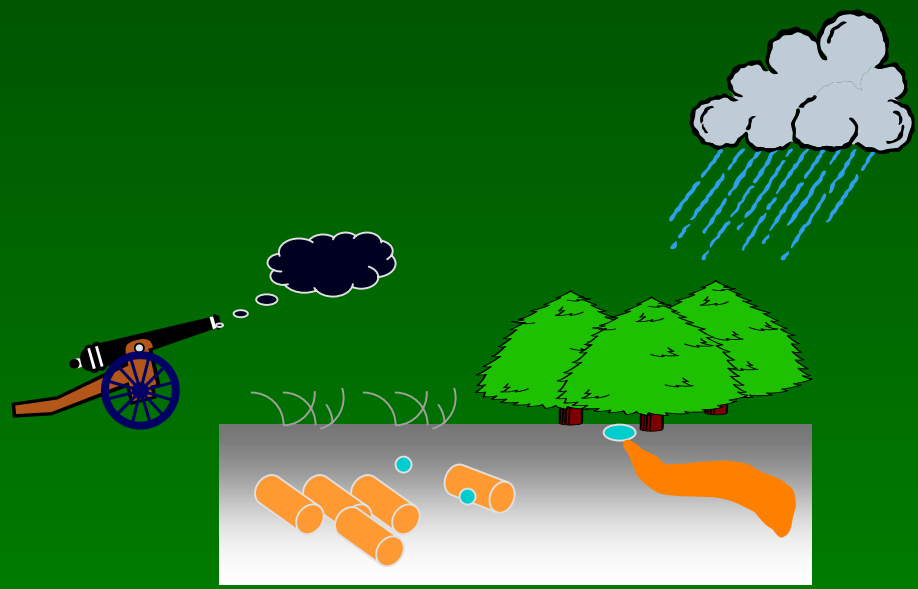
Outline

- Munitions Source Terms
- Various Transport Pathways
- Relative Rates of Release
- Corrosion
  - Problems & Objectives
  - Prior Work - Models & Romanoff
  - Work to Date
  - Assumptions
  - Approach/ Sample Parameters
- What we don't know & what we do know

Potential Munitions Source Terms

- High order detonations
- Low order detonations (rate~0.28%)
- UXO (3.45% overall dud rate ~20yrs)
  - Mechanical or corrosion
  - Ruptured rounds
- OB/OD
- Buried caches



Potential Pathways

- Surface water (high order,low order, OB/OD)
- Air (primarily high order)
- Groundwater (ALL potential sources)

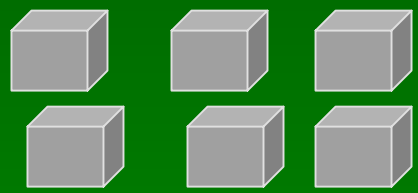
Relative Rates of Release

- Chemicals & mass in each category?

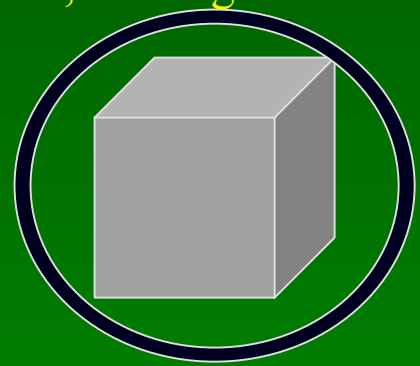
  We are here ★
- How much surface area is exposed of each source category?
- At what point in time is this surface area exposed?

High order =
very small mass/ordnance,
many ordnance,
very high surface area,
instantaneously exposed

Low order (.28%)
= nearly same mass as dud,
higher surface area,
instantaneously exposed



Dud (3.5%)= delayed exposure, low surface area and diffusion must take place first, but large mass



Corrosion: Problem & Objectives

- Problem: UXO source term unknown

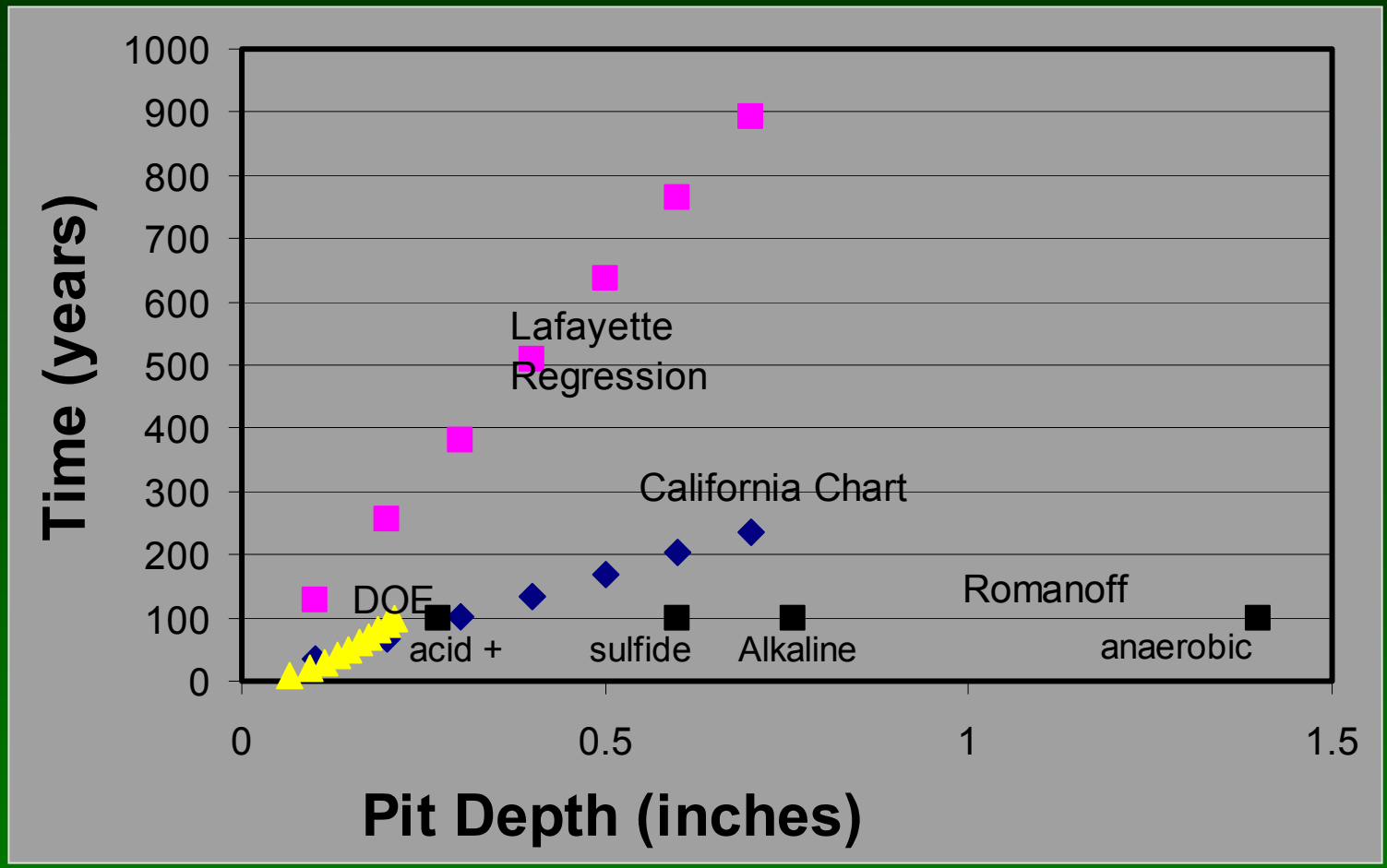
- Objectives:
  - Identify UXO perforation mechanism
  - Identify UXO perforation characteristics (size, shape, placement)
  - Confidently predict time to perforation in soil
  - Characterize energetic concentrations

Prior work - UXO Corrosion
MODELS & Data Sets

- California Chart for Culverts
  - Resistivity
  - pH
- DECHEMA is qualitative (soil type, salts etc.)
- Lafayette Regression equation (our '99 work)
  - Resistivity, HCO_3, Cations
- DOE quantitative (time, temperature)
- Romanoff prolific data on metals in various soils

Prior Work - UXO Corrosion

MODELS vs Romanoff's data



Prior Work - UXO Corrosion

Order-of-Magnitude Estimates

- Romanoff max. penetration:
  - 1)aerated & acid 0.27 “/100 yr
  - 2) poorly aerated 1.4 “/100 yr
  - 3) alkaline & salts 0.76 “/100 yr
  - 4) sulfides 0.6 “/100 yr
- Munitions Thickness
  - grenades - 0.2 “ …14 yrs in worst soil
  - Mortars - 0.5” … 35.7 yrs in worst soil
  - Bombs - 2 “ …should be unperforated

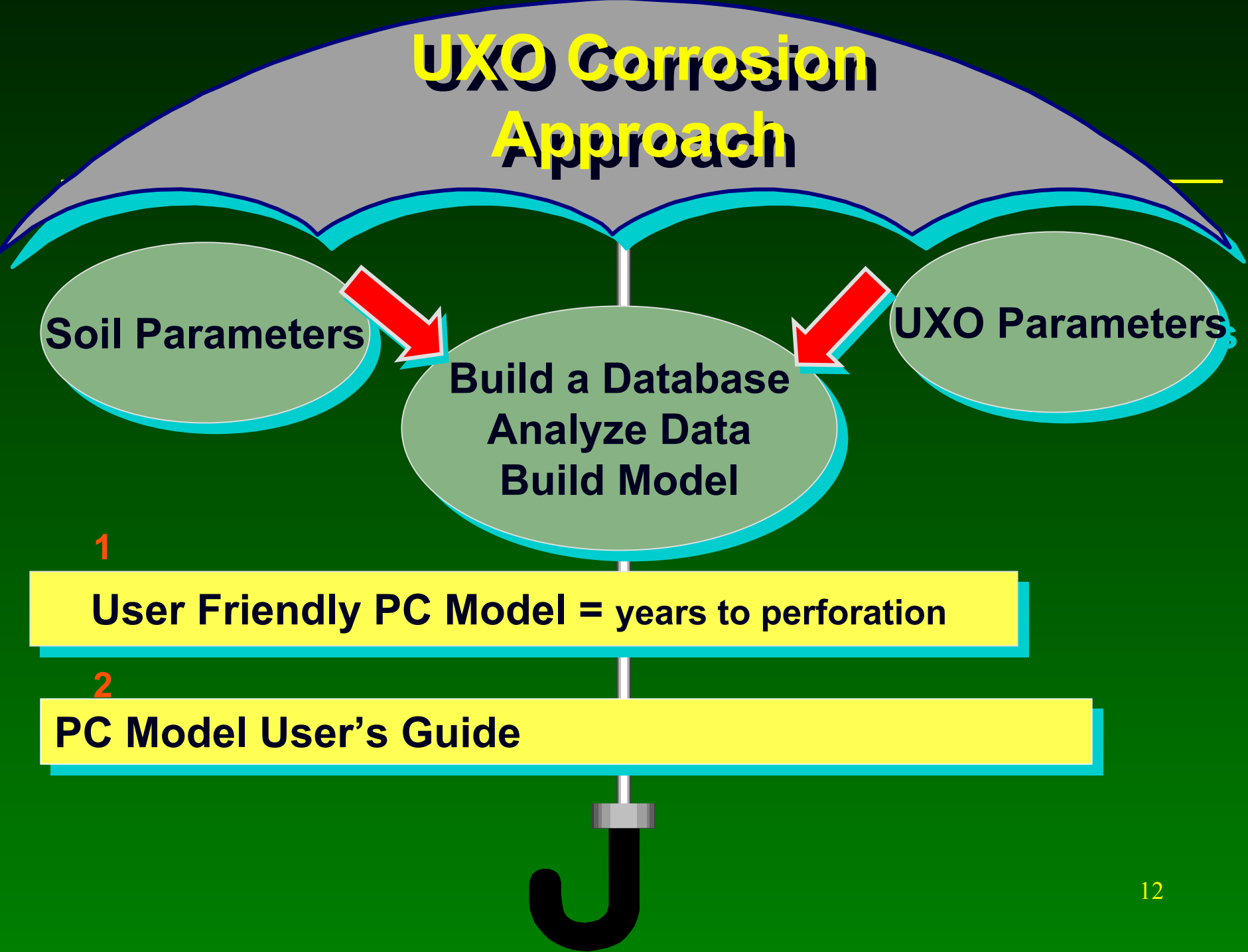
UXO Corrosion
Work to Date

- '98/'99 - Literature review & low fidelity model
- 7 UXO samples from 3 sites analyzed
- Ongoing- MMR- 100 data points
- Fundamental perforation data & model development - 200 additional data points at 6 ranges
- 15 UXO will be examined in detail for explosives beneath

UXO Corrosion
Current Assumptions

- Corrosion is an important element of fate and transport for UXO
- Corrosion from outside only
- Considering pitting corrosion, MIC, crevice, or SCC, as well as structural failure
- All metals are equal
- This work will take a new look at these assumptions - by collecting data on real UXO

UXO Corrosion Approach



UXO Corrosion
Potential Sample Parameters

- Grain-Size Analysis
- Resistivity
- Moisture Content
- Bulk Density
- Total Porosity
- permeability
- Plasticity

- Aerobic Bacteria
- Anaerobic Bacteria
- Sulfate Reducing Bacteria
- Acid Producing Bacteria
- Size of Populations
- Microscopic Bacteria Analysis

- pH
- Buffering Capacity
- Sodium
- Sulfate
- Sulfide
- Chloride
- Redox potential
- Total Dissolved Solids

- X-ray Diffraction
- Pit Depth & count
- Surface Area
- Hardness
- Micro Examination
- Chemical Analysis

- Photographs
- Deformation
- Closure integrity
- Perforation Size/ Shape/ Placement

POTENTIAL KNOWN AGE SITES

- Beale AFB - CA
- Camp Maxie - TX
- Buckley - CO
- Conway - SC
- Camp Cross - SC

What We Don't Know

- Physical characteristics of the sources (mass, surface area, high order deposits composition)
  - How do we characterize pore fluids in the unsaturated zone
  - How do we physically characterize surface energetic particulates?
- Time to release for duds
- After initial release: relative proportions of diffusion, advection, dispersion, adsorption, degradation

If the source is small enough…does anything get to the water table?

What We Know

- Parameters that influence range constituents transport (REST application)
  - Mass
  - Vertical - 24-hour storm event, sediment characteristics, vegetation, slope
  - Air - sediment characteristics, vegetation, wind speed
- Explosives adsorb to clays & organics similar to Lead, except RDX
- Explosives degrade aerobically (unlike lead), except RDX